

J/ψ measurements in the STAR experiment

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Abstract. In this paper, we present recent STAR J/ψ results. J/ψ nuclear modification factors (R_{AA}) in Au+Au collisions at $\sqrt{s_{NN}} = 200, 62.4$ and 39 GeV and in U+U collisions at $\sqrt{s_{NN}} = 193$ GeV are measured and compared to different theoretical calculations. We also report J/ψ elliptic flow (v_2) results in Au+Au collisions at $\sqrt{s_{NN}} = 200$ GeV and the first $\psi(2S)$ to J/ψ ratio measurement in $p + p$ collisions at $\sqrt{s} = 500$ GeV.

1 Introduction

It was proposed that quarkonia are dissociated in the hot medium due to the Debye screening of the quark-antiquark potential and thus this "melting" can be a signature of Quark-Gluon Plasma (QGP) formation [1]. But there are other mechanisms that can alter quarkonium yields in heavy-ion collisions relative to $p + p$ collisions, for example statistical recombination of heavy quark-antiquark pairs in the QGP or cold nuclear matter (CNM) effects. Systematic measurements of the quarkonium production for different colliding systems, centralities and collision energies may help to understand the quarkonium production mechanisms in heavy-ion collisions as well as the medium properties.

2 J/ψ and $\psi(2S)$ measurements

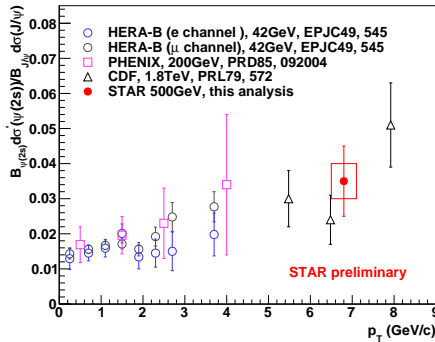


Figure 1. Ratio of $\psi(2S)$ to J/ψ in $p + p$ collisions at $\sqrt{s} = 500$ GeV from STAR (red circle) compared to results from other experiments at different energies.

STAR has measured J/ψ p_T spectra [7, 11] and polarization [12] in $p + p$ collisions at $\sqrt{s} = 200$ GeV via the dielectron decay channel ($B_{ee} = 5.9\%$) at mid-rapidity ($|y| < 1$). These results are compared to different model predictions to understand J/ψ production mechanism in elementary collisions. In order to further test the charmonium production mechanism and constrain the feed-down contribution from the excited states to the inclusive J/ψ production, the J/ψ and $\psi(2S)$ signals were extracted in $p + p$ collisions at $\sqrt{s} = 500$ GeV. Figure 1 shows $\psi(2S)/J/ψ$ ratio from STAR (red full circle) compared to measurements of

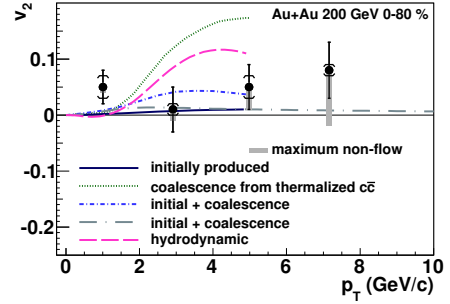


Figure 2. J/ψ v_2 in Au+Au collisions at $\sqrt{s_{NN}} = 200$ GeV at mid-rapidity in 0-80% central events [2] with different model predictions ([3–6]). The gray boxes represent a non-flow estimation.

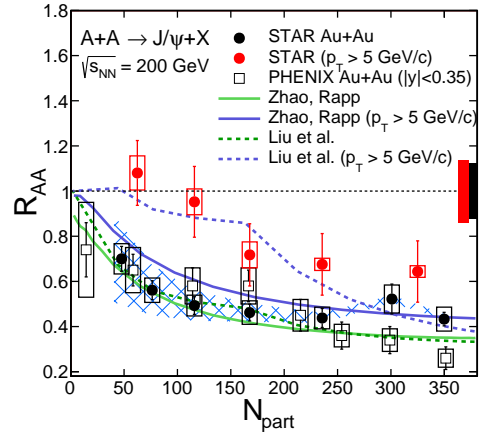


Figure 3. J/ψ R_{AA} as a function of N_{part} in Au+Au collisions at $\sqrt{s_{NN}} = 200$ GeV at mid-rapidity ([7, 8]) with two model predictions ([9, 10]). The low- p_T (< 5 GeV/c) result is shown as black full circles and the high- p_T (> 5 GeV/c) measurement as red full circles.

other experiments at different colliding energies, in $p + p$ and $p + A$ collisions. The STAR data point is consistent with the observed trend, and no collision energy dependence of the $\psi(2S)$ to J/ψ ratio is seen with current precision.

In Au+Au collisions at $\sqrt{s_{NN}} = 200$ GeV STAR has measured J/ψ p_T spectra for different centrality bins [7, 8]. It was found that at low p_T ($\lesssim 2$ GeV/c) the J/ψ p_T spectra are softer than the Tsallis Blast-Wave prediction, assuming that J/ψ flows like lighter hadrons [8]. This suggests that recombination may contribute to low- p_T J/ψ production. Measurement

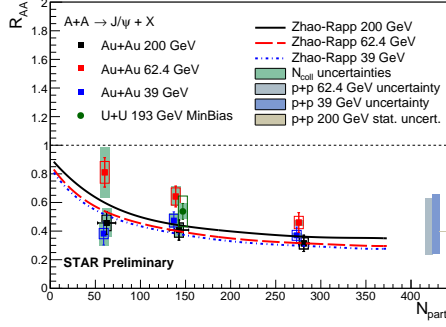


Figure 4. J/ψ R_{AA} as a function of N_{part} in Au+Au collisions at $\sqrt{s_{NN}} = 200$ (black), 62.4 (red) and 39 (blue) GeV at mid-rapidity with model predictions ([9]). As the green circle the minimum bias U+U measurement at $\sqrt{s_{NN}} = 193$ GeV is also presented.

of J/ψ v_2 may provide additional information about the J/ψ production mechanisms. Figure 2 shows J/ψ v_2 measured in STAR in Au+Au collisions at $\sqrt{s_{NN}} = 200$ GeV [2]. At $p_T > 2$ GeV/c v_2 is consistent with zero. Compared to different model predictions [3–6], data disfavor the scenario that J/ψ with $p_T > 2$ GeV/c are dominantly produced by recombination (coalescence) from thermalized $c\bar{c}$ pairs. Figure 3 shows J/ψ R_{AA} as a function of the number of participant nucleons (N_{part}) in Au+Au collisions at $\sqrt{s_{NN}} = 200$ GeV, separately for low- (< 5 GeV/c) [8] and high- p_T (> 5 GeV/c) [7] regions. Suppression increases with collision centrality and the R_{AA} at high p_T is systematic higher than the low- p_T one. The strong suppression of high- p_T J/ψ observed in central collisions (0-30%) indicates color screening or other QGP effects – at $p_T > 5$ GeV/c J/ψ are expected to be less affected by the recombination and CNM effects. The R_{AA} results are compared with two models, Zhao and Rapp [9] and Liu *et al.* [10]. Both models take into account direct J/ψ production with the color screening effect and J/ψ produced via the recombination of c and \bar{c} quarks. The Zhao and Rapp model also includes the J/ψ formation time effect and the B-hadron feed-down contribution. At low p_T both predictions are in agreement with the data, while the high- p_T result is well described by the Liu *et al.* model and the model of Zhao and Rapp underpredicts the measured R_{AA} .

Low- p_T J/ψ R_{AA} measurements in Au+Au collisions at various colliding energies: $\sqrt{s_{NN}} = 200$ (black), 62.4 (red) and 39 (blue) GeV are shown in Fig. 4. Within the uncertainties, a similar level of suppression is observed for all three energies, which can be described by the model predictions of Zhao and Rapp [9]. However, it should be noted that due to lack of precise $p + p$ measurements at 62.4 and 39 GeV Color Evaporation Model calculations [13] are used as baselines, which introduce large uncertainties. Figure 4 also shows the Minimum Bias R_{AA} measure-

ment in U+U collisions at $\sqrt{s_{NN}} = 193$ GeV as a full circle. In U+U collisions one can reach up to 20% higher energy density compared to Au+Au collisions in the same centrality bin [14]. No difference in suppression compared to other measurements presented in Fig. 4 is observed.

3 Summary

In summary, significant suppression of low p_T J/ψ is seen in Au+Au collisions at various colliding energies: $\sqrt{s_{NN}} = 200$, 62.4 and 39 GeV, and in U+U collisions at $\sqrt{s_{NN}} = 193$ GeV. No strong energy dependence of the J/ψ suppression in Au+Au is observed. Also, high- p_T J/ψ in Au+Au collisions at $\sqrt{s_{NN}} = 200$ GeV are strongly suppressed in central collisions, which suggests the QGP formation. $\psi(2S)$ to J/ψ ratio was measured for the first time in $p + p$ collisions at $\sqrt{s} = 500$ GeV. When compared to results from other experiments, no collision energy dependence of the ratio is seen.

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